

DEPARTMENT OF ENERGY	LESSON PLAN
	Course: Radiological Control Technician  Unit: Fundamental Academics  Lesson: 1.08 Biological Effects of Radiation
<p>Learning Objectives:</p> <p>1.08.01 Identify the function of the following cell structures:</p> <ul style="list-style-type: none"> <li>a. Cell membrane</li> <li>b. Cytoplasm</li> <li>c. Mitochondria</li> <li>d. Lysosome</li> <li>e. Nucleus</li> <li>f. DNA</li> <li>g. Chromosomes</li> </ul> <p>1.08.02 Identify effects of radiation on cell structures.</p> <p>1.08.03 Identify the law of Bergonie and Tribondeau.</p> <p>1.08.04 Identify factors which affect the radiosensitivity of cells.</p> <p>1.08.05 Given a list of types of cells, identify which are most or least radiosensitive.</p> <p>1.08.06 Identify primary and secondary reactions on cells produced by ionizing radiation.</p> <p>1.08.07 Identify the following definitions and give examples of each:</p> <ul style="list-style-type: none"> <li>a. Stochastic effect</li> <li>b. Non-stochastic effect</li> </ul> <p>1.08.08 Identify the LD 50/30 value for humans.</p> <p>1.08.09 Identify the possible somatic effects of chronic exposure to radiation.</p> <p>1.08.10 Distinguish between the three types of the acute radiation syndrome, and identify the exposure levels and the symptoms associated with each.</p> <p>1.08.11 Identify risks of radiation exposure to the developing embryo and fetus.</p> <p>1.08.12 Distinguish between the terms "somatic" and "heritable" (or "genetic") as they apply to biological effects.</p>	

References:

1. "Radiation Biology"; Casarett, Alison; Prentice-Hall, Inc.; 1968
2. "A Catalog of Risks"; Cohen, Bernard; Health Physics, Volume 36, pg. 707-722; 1979
3. "Basic Radiation Protection Technology"; Gollnick, Daniel; Pacific Radiation Press; 1983
4. "The Effects on Population of Exposure to Low Levels of Ionizing Radiation"; National Academy of Sciences; 1972
5. "Ionizing Radiation Levels and Effects"; United Nations, Volume II - Effects; New York; 1972
6. "Health Effects of Exposure to Low Levels of Ionizing Radiation"; Biological Effects of Ionizing Radiation (BEIR) Report V; National Research Council; 1990

Instructional Aides:

Overheads, overhead projector/screen, chalkboard/whiteboard

**I. LESSON INTRODUCTION****A. Self Introduction**

1. Name
2. Phone number
3. Background

**B. Motivation**

The biological effects radiation has on the human body has led to current radiation control programs. An RCT must have some basic understanding of the methods in which radiation may cause biological damage to protect themselves and the workers from unnecessary exposure to ionizing radiation.

**C. Lesson Overview**

1. Cellular structure and damage
2. Radiosensitivity
3. Stochastic/non-stochastic effects
4. Chronic effects
5. Acute effects
6. Embryological effects
7. Heritable effects

**D. Introduce Objectives**

O.H.: Objectives

**II. LESSON OUTLINE****A. CELL STRUCTURE**

See Fig. 1 - "Basic Cell Structure"

1. Basic unit of life
  - a. Made up of protoplasm
    - 1) Carbohydrates
    - 2) Lipids
    - 3) Inorganic salts
    - 4) Proteins
    - 5) Nucleic acids

Objective 1.08.01

- 6) Gases
    - b. Consists of 70-80% water
    - c. Primary constituents:
      - 1) Membrane
      - 2) Cytoplasm
      - 3) Nucleus
  - 2. Cell Membrane
    - a. 100 angstroms thick
    - b. Regulates the concentration of water, salts, and organic matter
    - c. Capable of "active transport"
    - d. All waste products or secretions pass through the membrane
  - 3. Cytoplasm
    - a. Jelly-like substance in which the nucleus is suspended
    - b. Aqueous solution of proteins and salts
  - 4. Mitochondria
    - a. Power plant of the cell
    - b. Contains a special energy storing molecule called Adenosine Tri-Phosphate (ATP)
    - c. Supplies the energy for all cell activities
  - 5. Lysosome
    - a. Contains digestive enzymes which break down large molecules
  - 6. Cell Nucleus
    - a. Location of the nucleus varies with cell type
    - b. Directs all cell activity
    - c. Contains all the genetic material
  - 7. DNA/Chromosomes
- See Fig. 2 - "Double Helix"

- a. DNA (deoxyribonucleic acid) - master blueprint
- b. When the cell divides chromatic coils form chromosomes
- c. The number of chromosomes is fixed for a given species (Humans - 46)
- d. Chromosomes contain several hundred genes which are responsible for traits

See Fig. 3 - "DNA Base Pairs"

## **B. RADIATION DAMAGE TO CELL CONSTITUENTS**

### **1. Cell Membrane**

Objective 1.08.02

- a. It takes about 3,000 - 5,000 rad to rupture
- b. Results in leakage of beneficial material and introduction of potentially harmful fluids
- c. At lower doses, radiation increases the permeability and some leakage occurs

### **2. Cytoplasm**

- a. Negligible effect

### **3. Mitochondria**

- a. A "few thousand" rad will disrupt the function
- b. Interrupts the storage of energy via Adenosine Tri-Phosphate (ATP)
- c. If the cell has a large reserve of stored food, it can repair itself
- d. The greater the dose, the greater the damage, the longer the repair time
- e. If the repair time is too long and the food reserve fails, the cell dies from starvation

### **4. Lysosome**

- a. Ruptures between 500 and 1,000 rad
- b. Digestive enzymes are released and begin to digest the rest of the cell

### **5. Nucleus**

- a. Difficult to affix a dose because the nucleus is the most radiosensitive part of the cell
- b. Inhibits the ability of the cell to divide by affecting the DNA and RNA
- c. Without normal DNA the cell cannot produce a duplicate set of chromosomes
- d. The longer division is delayed the greater chance it will die; as the dose increases, the delay time lengthens

**C. RADIOSENSITIVITY**

Objective 1.08.03

1. The relative susceptibility of cells, tissues and organisms to the injurious action of radiation  
Found to be not all-inclusive, muscle and nerve tissue, are resistant, young or old
2. Law of Bergonie and Tribondeau (1906):
  - a. "The radiosensitivity of a tissue is directly proportional to its reproductive capacity and inversely proportional to its degree of differentiation"

3. Factors which affect a cells sensitivity to radiation  
Objective 1.08.04

- a. Cells are more sensitive if they have a high division rate
- b. The higher the metabolic rate in a cell, the lower its resistance to radiation
- c. Cells tend to be more sensitive if they are non- specialized
- d. Well nourished cells, or cells with a high level of oxygenation are more sensitive

4. Radiosensitive Tissues:
  - a. Germinal (reproductive) cells of the ovary and testis e.g., spermatogonia
  - b. Hematopoietic (bloodforming) tissues: red bone marrow, spleen, lymph nodes, thymus
  - c. Epithelium of the skin

- d. Epithelium of the gastrointestinal tract (interstitial crypt cells)
  - 5. Radioresistant Tissues:
    - a. Bone
    - b. Liver
    - c. Kidney
    - d. Cartilage
    - e. Muscle
    - f. Nervous tissue
  - 4. Radiosensitivity not only differs from one cell or tissue to another but also between individuals and genders
- Note: They do not follow the four general rules
- A whole body exposure of 600-700 R will kill most animals; however, even higher doses have been delivered to the brain for cancer treatment

#### **D. PRIMARY AND SECONDARY EFFECTS OF RADIATION**

Objective 1.08.06

- 1. Primary Effect
  - a. Ionization & Excitation of atoms making up the cell
  - b. Produced when the primary (initial) interaction of radiation is with the target atoms in the cell such as those in the DNA
- 2. Secondary Effects
  - a. Formation of free radicals which are very reactive and can chemically attack target molecules, such as DNA
  - b. Occurs with the disassociation of water

Water makes up 70 - 80% of the cell

Three possible reactions:

- 1)  $H$  interacting with  $H = H_2$
- 2)  $OH$  combining with  $H = H_2O$
- 3)  $OH + OH = H_2O_2$

- c. Formation of  $H_2O_2$  (hydrogen peroxide) can lead to cell death.  $H_2O_2$  is a harmful oxidizer which poisons the cell

#### **E. STOCHASTIC AND NON-STOCHASTIC EFFECTS**

Objective 1.08.07

##### 1. Stochastic Effects

- a. An effect in which the **PROBABILITY** of the effect occurring increases with the dose
- b. The effects have no established threshold, they can occur from the irradiation of only one cell; any exposure, however low, has some chance of causing the effect
- c. Two examples of stochastic effects: cancer and genetic mutations

##### 2. Non-Stochastic Effects (Deterministic)

- a. Effects in which the **SEVERITY** of the effect increases as the dose increases
- b. It is generally assumed that a threshold exists; and if doses received are below the threshold dose, no effects will occur
- c. Effects typically result from the collective injury of many cells
- d. Effects include: cataracts, skin burns, lowering of blood cell counts, etc.

#### **F. LD-50/30**

Objective 1.08.08

- 1. Implies that 50% of a population will die within 30 days with NO medical treatment
- 2. LD-50/30 for humans is 300 - 500 rads, and is typically stated as 450 rad

#### **G. EFFECTS OF CHRONIC EXPOSURES TO IONIZING RADIATION**

Objective 1.08.09

##### 1. Chronic exposure

- a. Typically refers to smaller exposures over a long time period



- b. No unique disease associated with radiation exposure, but there is a statistical increase in the risk of developing disease
  - c. Radium dial painters, radiologists, dentists, atomic bomb survivors provide evidence of induced effects in humans
2. Cancer
- a. Radiation induced cancers are justification for today's protection standards
  - b. Radiation can act as both an initiator and promotor of cancer
  - c. Possibility of inducing tumors
  - d. Radiation may cause cancer but also be used to treat cancer
3. Cataracts
- a. A cataract is an opacity of the lens of the eye
  - b. Exposures as small as 600 rad may produce a cataract for high LET radiation
  - c. Generally symptoms will not appear for years after the exposure
  - d. Effects may be cumulative
  - e. Neutrons and gamma are primary hazards
  - f. Exposures at younger ages increase susceptibility
4. Life Span (Shortening or Lengthening)
- a. Data is uncertain and firm conclusions are difficult to estimate.
  - b. Aging is the progressive deterioration of tissues along with declining functional capacities
  - c. Irradiated animals under lab conditions showed some cellular changes that can be associated with aging

- d. Low doses of .1 R/day or 100-400 R over a lifetime has indicated an increase in rat life time, and also a lower incidence of disease. This effect is known as Radiation Hormesis. No firm conclusions of this have been universally accepted.

## **H. EFFECTS OF ACUTE RADIATION EXPOSURES**

Objective 1.08.10

Acute exposures are those exposures which involve relatively large doses of radiation received over a relatively short period of time.

1. Stages
  - a. Prodromal
  - b. Latent
  - c. Illness
  - d. Recovery/death
2. Three syndromes
  - a. Hematopoietic Syndrome
    - 1) Also called "Therapeutic Range" because treatment can play a large role
    - 2) Dose level - Between 200 to 1,000 rads - (Some blood changes can be seen @ lower doses)
    - 3) Critical organs are the blood forming organs
    - 4) Affects the production of white blood cells - Leukopenia - decreased ability to fight infection
    - 5) Lowered platelet count causes hemorrhaging and slowing of the healing process
    - 6) Symptoms:
      - a) Nausea and vomiting
      - b) Epilation

- 7) Treatment - antibiotics to fight infection  
- bone marrow transplants to replace damaged cells, (uncertain if this works)
- 8) If death does occur it will be due to infection and hemorrhaging
- b. Gastrointestinal Syndrome
  - 1) Dose level - Between 1,000 - 5,000 rads
  - 2) Affects the GI tract
  - 3) Stops the production of new epithelial cells which line the wall of the intestines and are responsible for absorption of nutrients and control body fluid metabolism
  - 4) Symptoms:
    - a) appear in a few hours
    - b) nausea and vomiting
    - c) dehydration from diarrhea and low nutrient absorption
    - d) electrolyte imbalance
  - 7) Cause of death: circulatory collapse from loss of fluids
- c. Central Nervous System (CNS) Syndrome
  - 1) Dose level:
    - a) >5,000 rad
  - 2) Critical Organ:
    - a) Central Nervous System
  - 3) Symptoms:
    - a) Convulsions
    - b) tremors
    - c) ataxia
    - d) lethargy
  - 4) Cause of death:

a) Respiratory failure and/or brain edema

3. In the event an individual survives an acute exposure of high dose, they run an increase risk of latent effects

**I. EFFECTS ON THE EMBRYO/FETUS**

Objective 1.08.11

1. According to the law of Bergonie and Tribondeau, children are more radiosensitive than adults, fetuses more than children, and embryos are the most radiosensitive.
2. Radiation doses may cause death or abnormalities
3. Most critical period 2 to 6 weeks gestation - most organs formed
4. Doses as low as 25 rad may cause defects.
5. Reported effects include blindness, cataracts, mental deficiency, coordination defects, deformed arms legs, and general mental/physical subnormality
6. An exposure of 400 - 600 rad during the first trimester (excluding the first week) of pregnancy is sufficient to cause fetal death and spontaneous abortion

**J. GENETIC EFFECTS**

Objective 1.08.11

1. Differences in the genetic structure of somatic and germ cells
2. Mutations can be produced in genes by radiation
3. Dominant genes will generally determine characteristics when the 23 chromosome pairs are matched
4. In order for a recessive gene to determine a characteristic it must be paired with another recessive gene
5. This indicates mutations may not appear for several generations

- 6. Doubling Dose - double natural mutation rate - estimated to be greater than 100 rem (1 Sv)      Reference: BEIR V
- 7. Radiation damage in humans can result in both somatic and heritable effects
  - 1) Somatic effects - Effects which occur in the exposed individual.
  - 2) Heritable effects - effects which occur in the future generations of the exposed individual.

**IV. SUMMARY**

A. Review major topics

- 1. Cellular structure and damage
- 2. Radiosensitivity
- 3. Stochastic/non-stochastic effects
- 4. Chronic effects
- 5. Acute effects
- 6. Embryological effects
- 7. Heritable effects

B. Review learning objectives

**V. EVALUATION**

Evaluation shall consist of a written examination comprised of multiple choice questions. 80% shall be the minimum passing criteria for the examination.